JET STRUCTURE TOPICAL GROUP REPORT

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sPHENIX Stated Jet Physics Goals

The key to the physics is to cover jet energies of 20–70 GeV, for all centralities, for a range of jet sizes, with high statistics and performance insensitive to the details of jet fragmentation

- JER < 120%/$\sqrt{E_{\text{jet}}}$ in p+p for R = 0.2–0.4 jets
- JES Uncertainty < 3% for inclusive jets
- Energy measurement insensitive to softness of fragmentation (quarks or gluons) — HCal + EMCal
- Trigger to select jets without bias

sPHENIX Stated DiJet Physics Goals

The key to the physics is large acceptance in conjunction with the general requirements for jets as above

- Greater than 80% containment of the opposing jet axis
- Greater than 70% full containment for R = 0.2 dijets
- R_{AA} and A_J measured with < 10% systematic uncertainty
  - Also key in p+A → onset of quenching effects

sPHENIX Stated Fragmentation Function Physics Goals

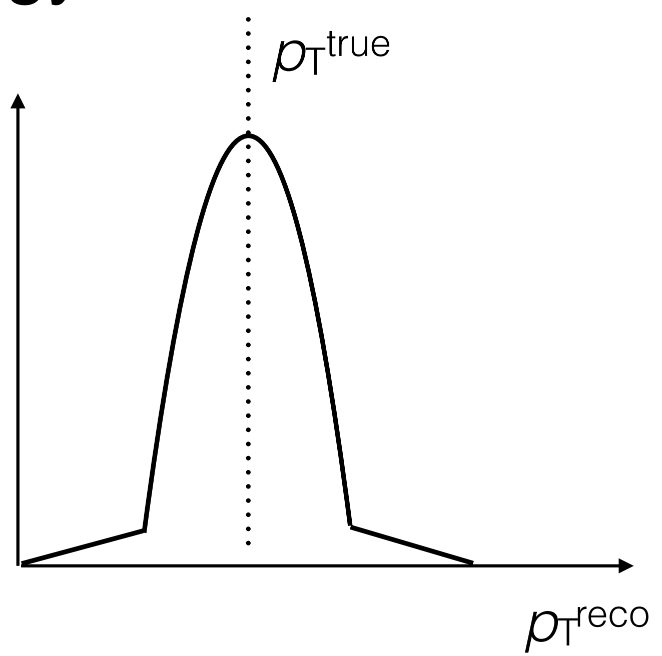
The key to the physics is unbiased measurement of jet energy

- Excellent tracking resolution out to greater than 40 GeV/*c*
  - $dp/p < 0.2\% \times p$
- Independent measurement of p and E ($z = p/E$)
  - No difficult to untangle autocorrelations

Descoping options

Tracking and calorimetry are the biggest questions for jet structure

- Tracking affects charged particle measurements
  - Need to quantify efficiency/resolution/purity inside jet cone
- EMCal+HCal options affect jet energy measurements
  - Need to quantify jet response
    - Resolution
    - Non-Gaussian tails
- In following slides we will show the current status of answering these issues



Descoping options - EMCal

Reduce Acceptance ~$|\eta|<0.6$

- Jet energy measurements affected across the boundary
- Statistics reduced for both photons and fully contained inclusive jets
- Statistics reduction checked at generator level
- Jet resolution with only HCal?

Ganging towers together

- Not key for jet structure → Good photon performance needed to calibrate JES

Simulation samples

- **High p_T jet sample** allows us to study:
  - The effect of the thinned HCal on the jet response
  - The effect of the ganged EMCal towers on the jet response
  - High p_T jets produced at mid-rapidity, so will not elucidate the effect of ½ EMCal
- **Low p_T jet sample** allows us to study
  - ½ EMCal as these jets will have a wider η range
  - p_T dependence of inclusive jet response

Simulations Generated for Descoping Investigation 1 of 2

N_{evt} = 10k of p_T = 50-55 GeV dijet events Generated with PYTHIA8

- Generate falling jet spectrum with truth-level filtering
  - Keep events with at least one R=0.4 truth jet with 50 GeV $< p_T <$ 55 GeV and $|\eta| < 0.6$.
- HardQCD:all
- PhaseSpace:pTHatMin = 45.0
- PYTHIA events only — want to know jet response from detector, not from UE
- /phenix/upgrades/decadal/dvp/GeneratorInputFiles/

Simulations Generated for Descoping Investigation 2 of 2

N_{evt} = 10k of p_T = 25-30 GeV dijet events Generated with PYTHIA8

- Generate falling jet spectrum with truth-level filtering
  - Keep events with at least one R=0.2 truth jet with 25 GeV < p_T < 30 GeV and $|\eta| < 0.9$.
- Required to fully measure the effect of the reduced EMCal acceptance on the jet response

GEANT4 Simulations

High p_T sample run through 3 Calo configurations:

- Nominal
- 1/2 EMCal
- Thin HCal

Total of 30k G4 dijet events

- /sphenix/sim/sim01/production/aldcharge/pythia8/pythia8dijet/50-55GeV/
- Note: EMCal run with 1D Spacal geometry for memory considerations

Key observable: jet energy *response* p_T^{reco} / p_T^{true}

GEANT4 Simulations

Low p_T sample run through 2 Calo configurations:

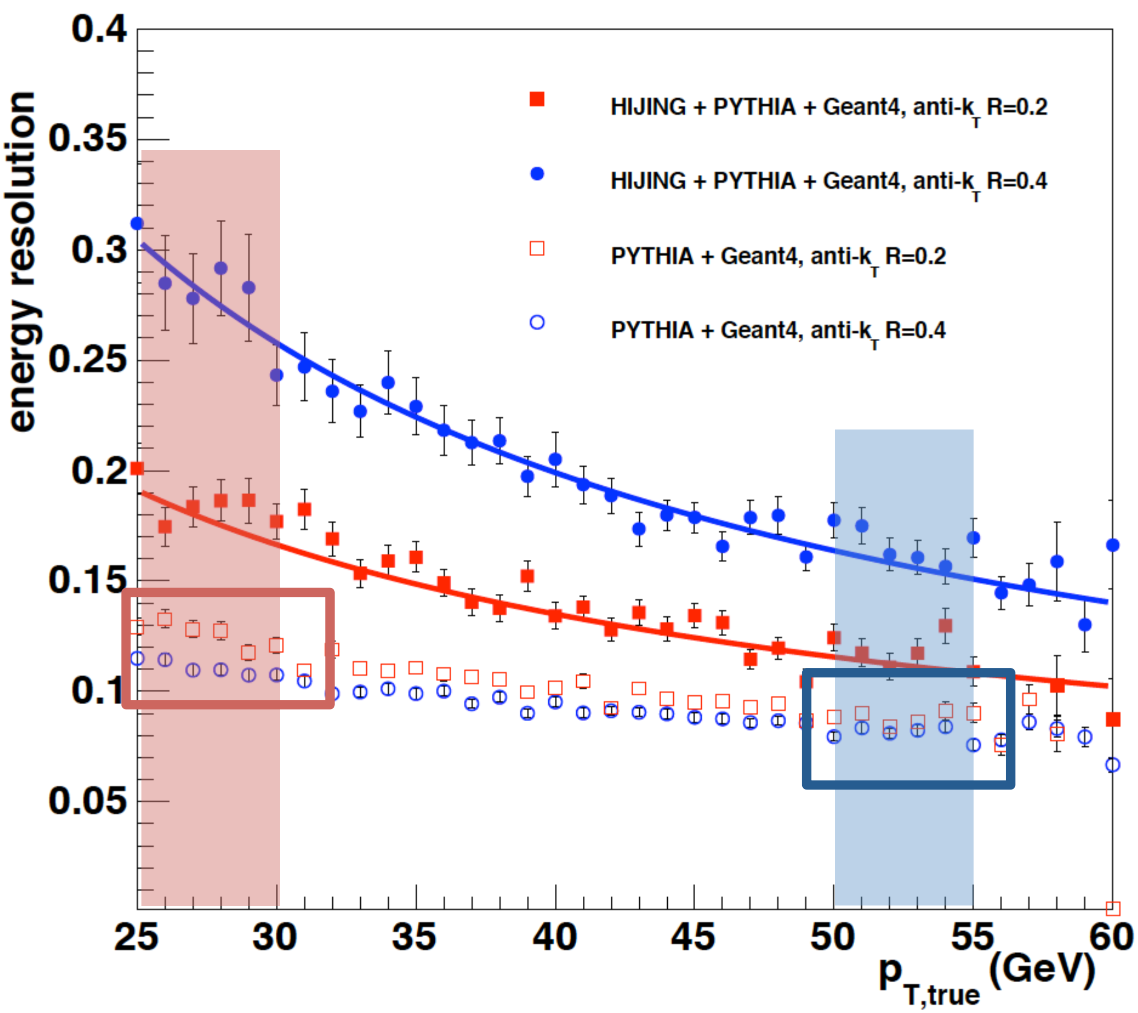
- Nominal
- 1/2 EMCal

Total of 20k G4 dijet events

- /sphenix/sim/sim01/production/aldcharge/pythia8/pythia8dijet/R0p2pT25t30eta0/spacal1d/
- Note: EMCal run with 1D Spacal geometry for memory considerations

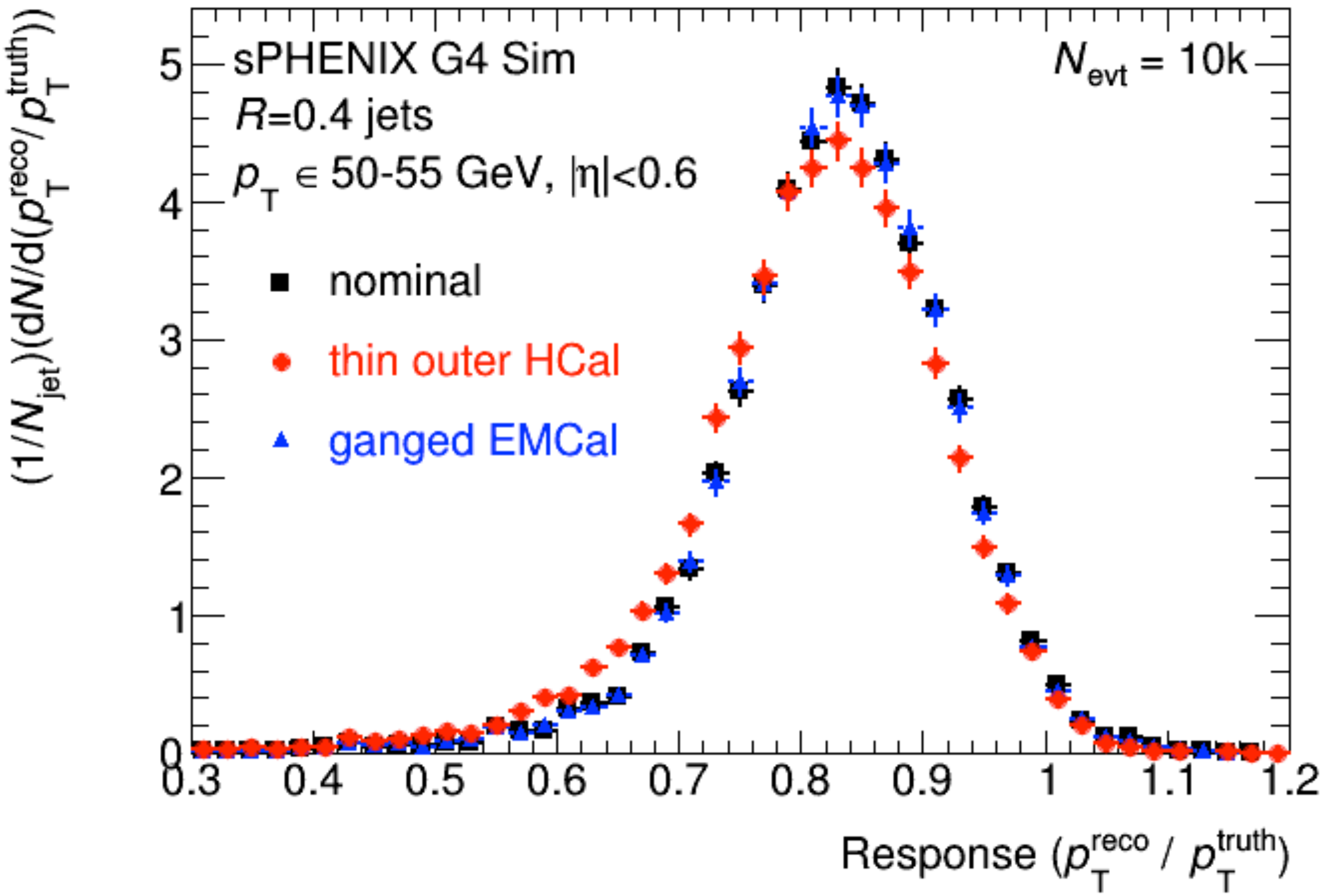
Key observable: jet energy *response* p_T^{reco} / p_T^{true} versus η

MIE JER versus $p_{T,jet}$



- **R = 0.4** jets effected more by UE
- Similar response in pp to R = 0.2 at $p_T > 50$ GeV
- JER affects unfolding uncertainty
- Ideal $p_{T,Reco}/p_{T,truth} \rightarrow 1$
  - JES

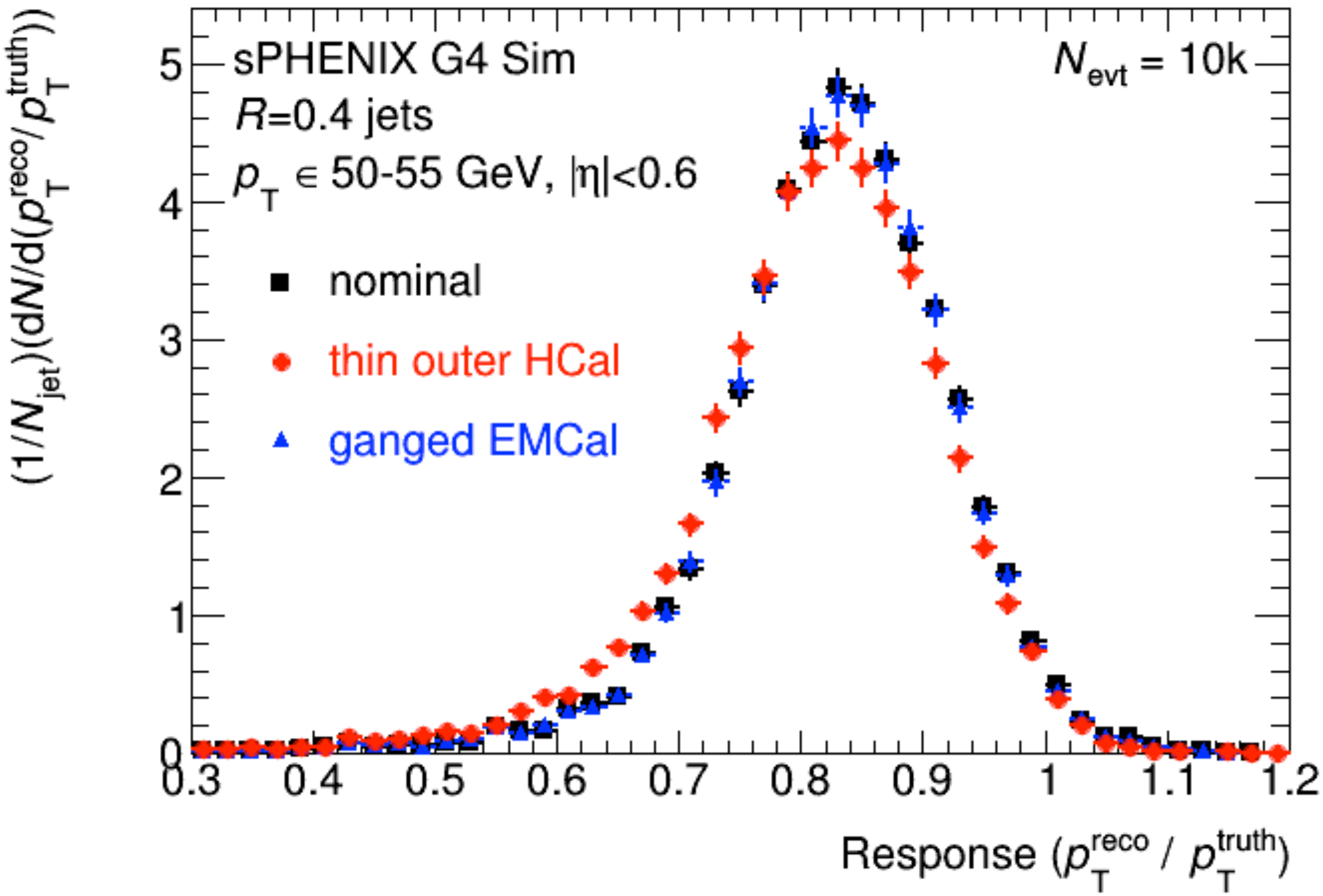
Inclusive Jet Response vs Calo Configuration



For inclusive jet measurements

- No significant effect due to the ganged EMCal
- Slight shift and broadening of the Response for thin HCAL but….

Inclusive Jet Response vs Calo Configuration



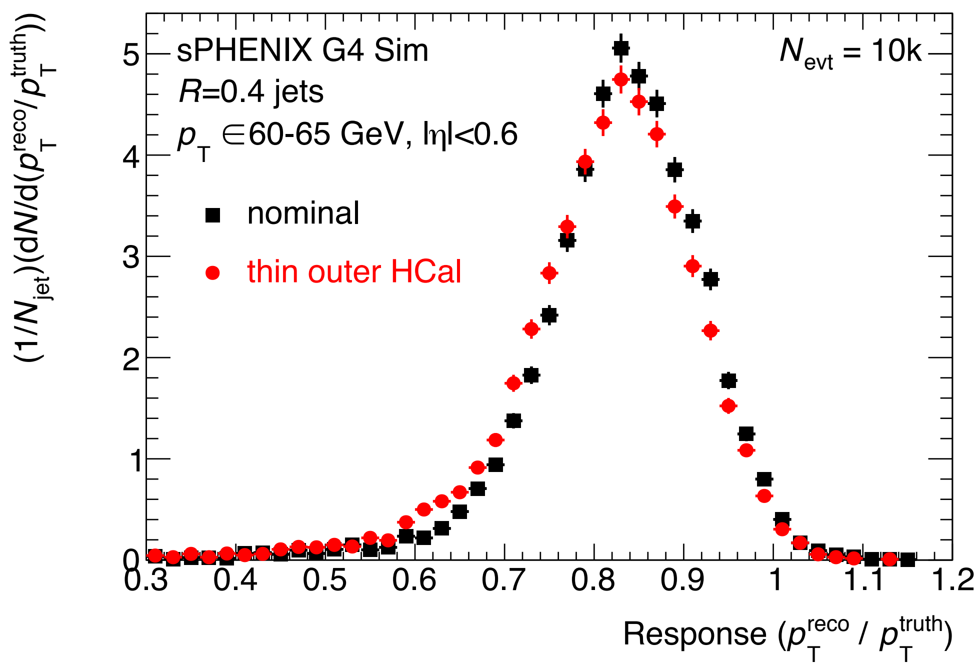
The devil is in the details → HCal response will depend on fragmentation

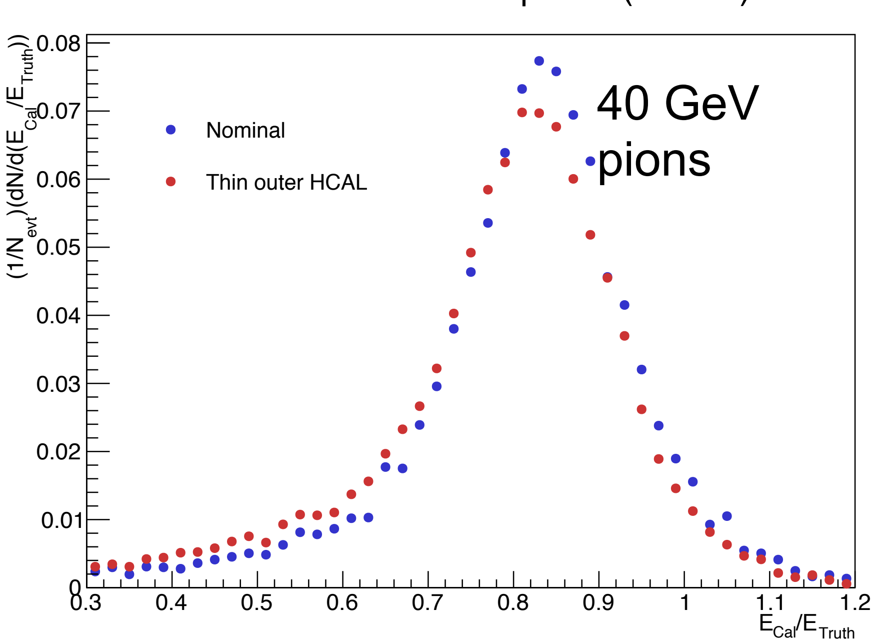
- High Z particles are more likely to “punch through” a thinner HCal
- Needs additional simulation to quantify

Fresh off the press!

Looked at higher p_T jets (60 - 65 GeV) this morning

- Result is similar to 50 – 55 GeV
- Additionally looked at 40 GeV pions → high z particles
- Very similar to jet results → 40 GeV hadrons do not seem to be punching through
- Preliminary from this morning, we need to look at this a little more

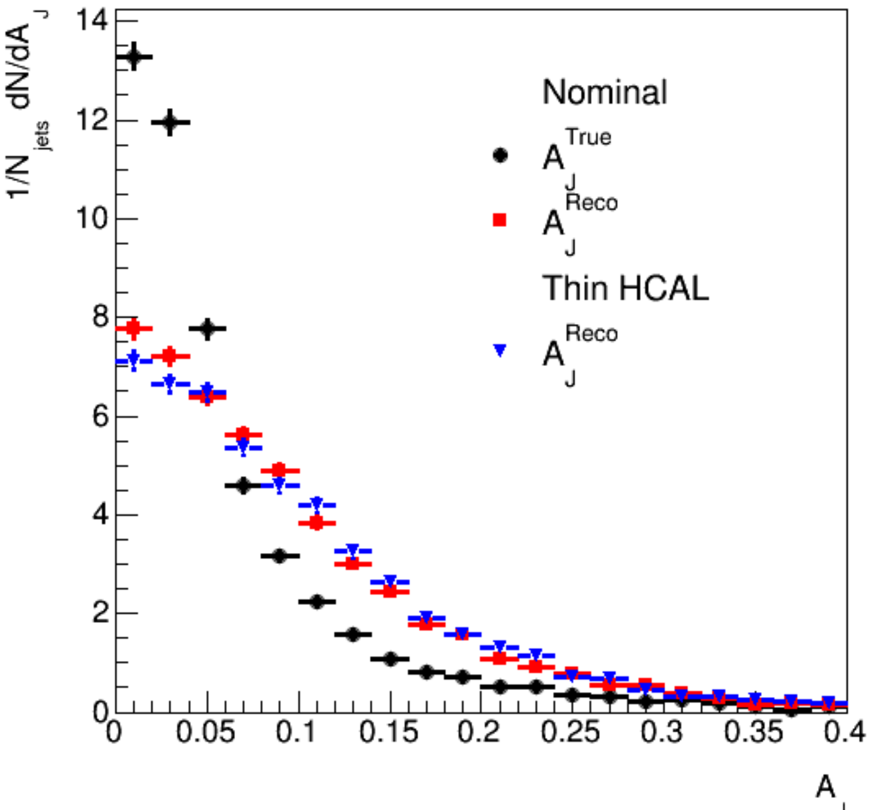




Jet Response for DiJet A_J Measurement

Difference in Jet Response between nominal and thin HCal has a minimal effect on reconstructed A_J

- Does not account for UE Fluctuations



$$A_J = \frac{p_{T,Leading} - p_{T,Subleading}}{p_{T,Leading} + p_{T,Subleading}}$$

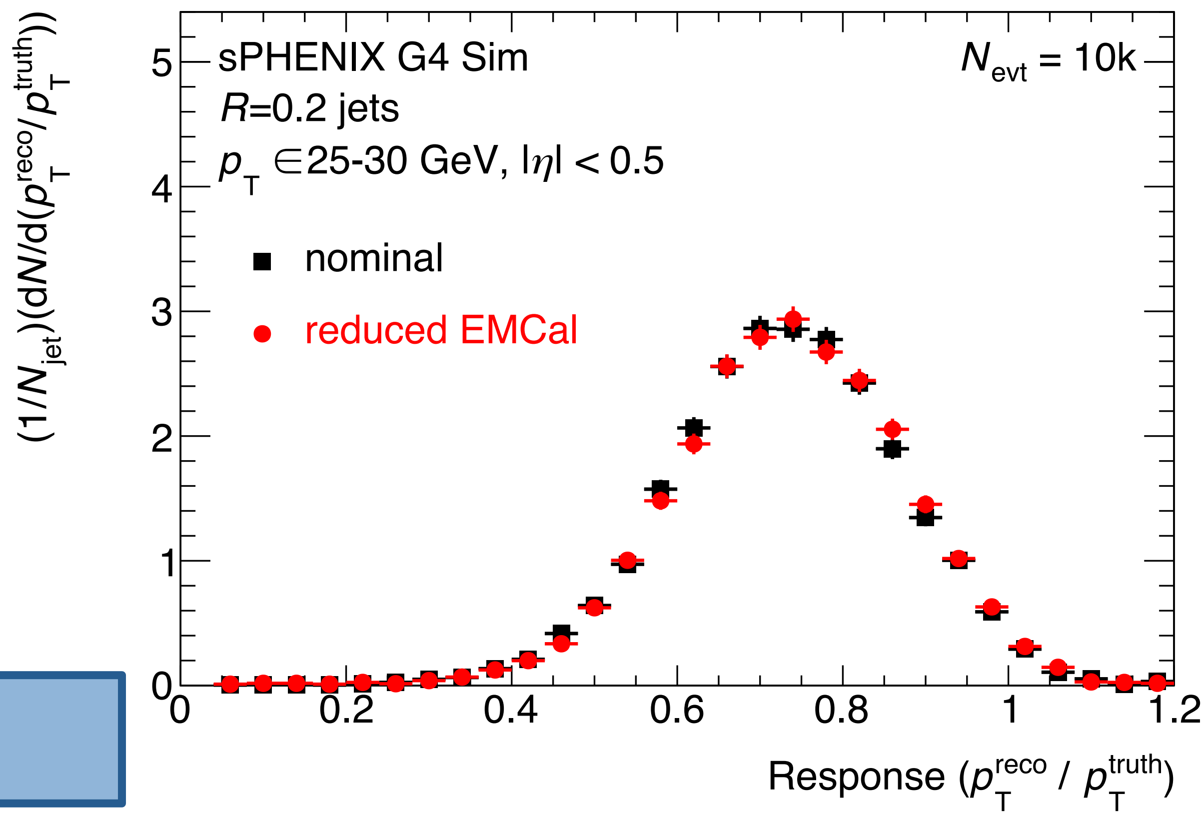
$p_{T,Reco} > 10$ GeV

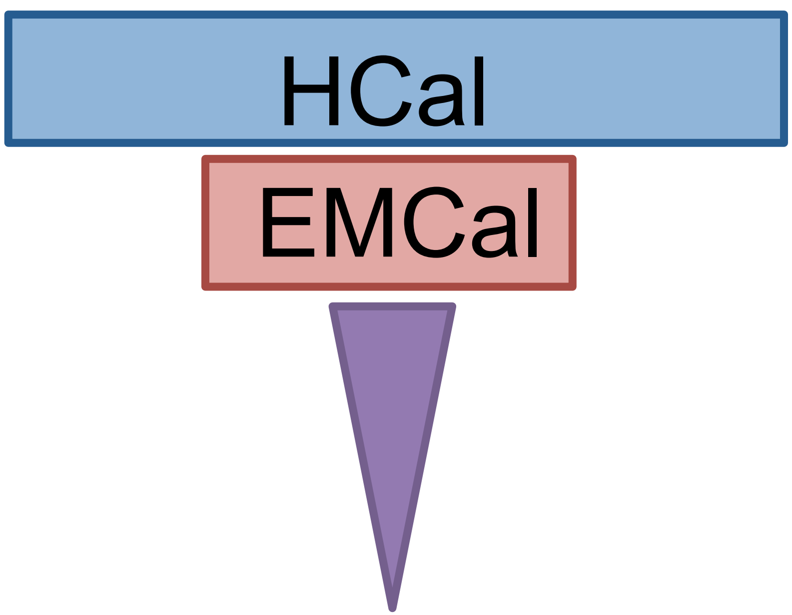
$|\Delta\phi| > 2.35$

1/2 EMCal

Fully Contained

- $|\eta| < 0.5$

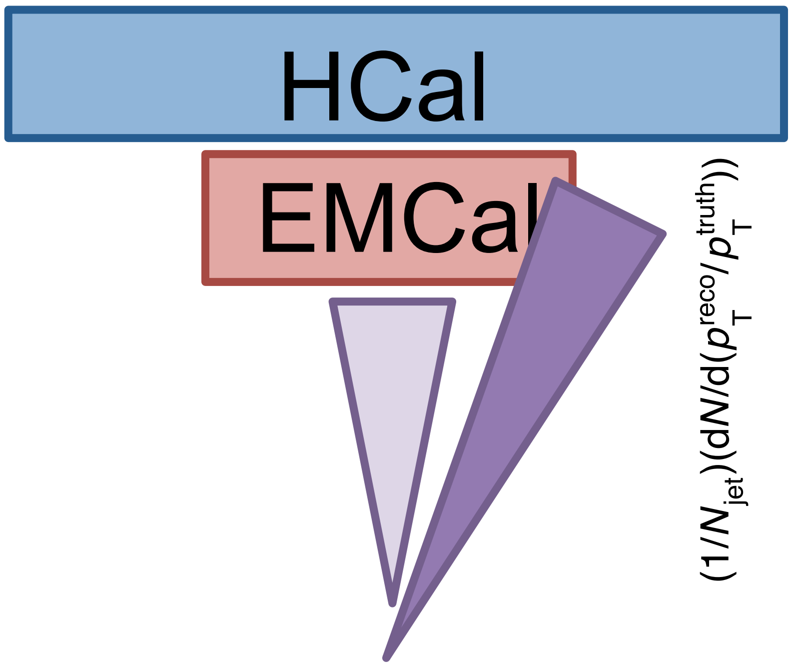


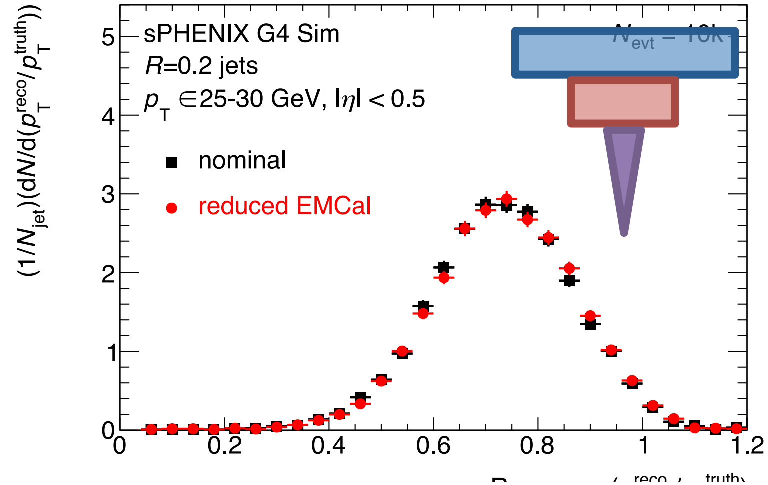


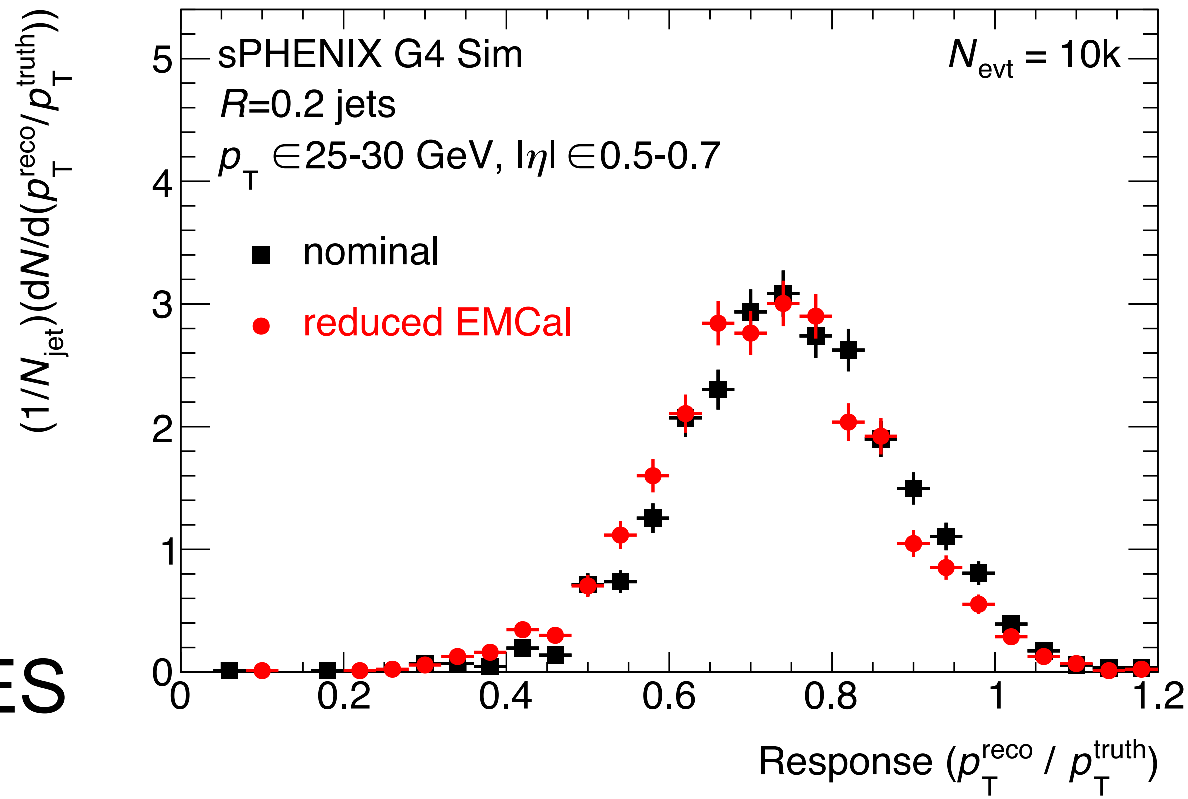
1/2 EMCal

Partially Contained

- $0.5 < |\eta| < 0.7$



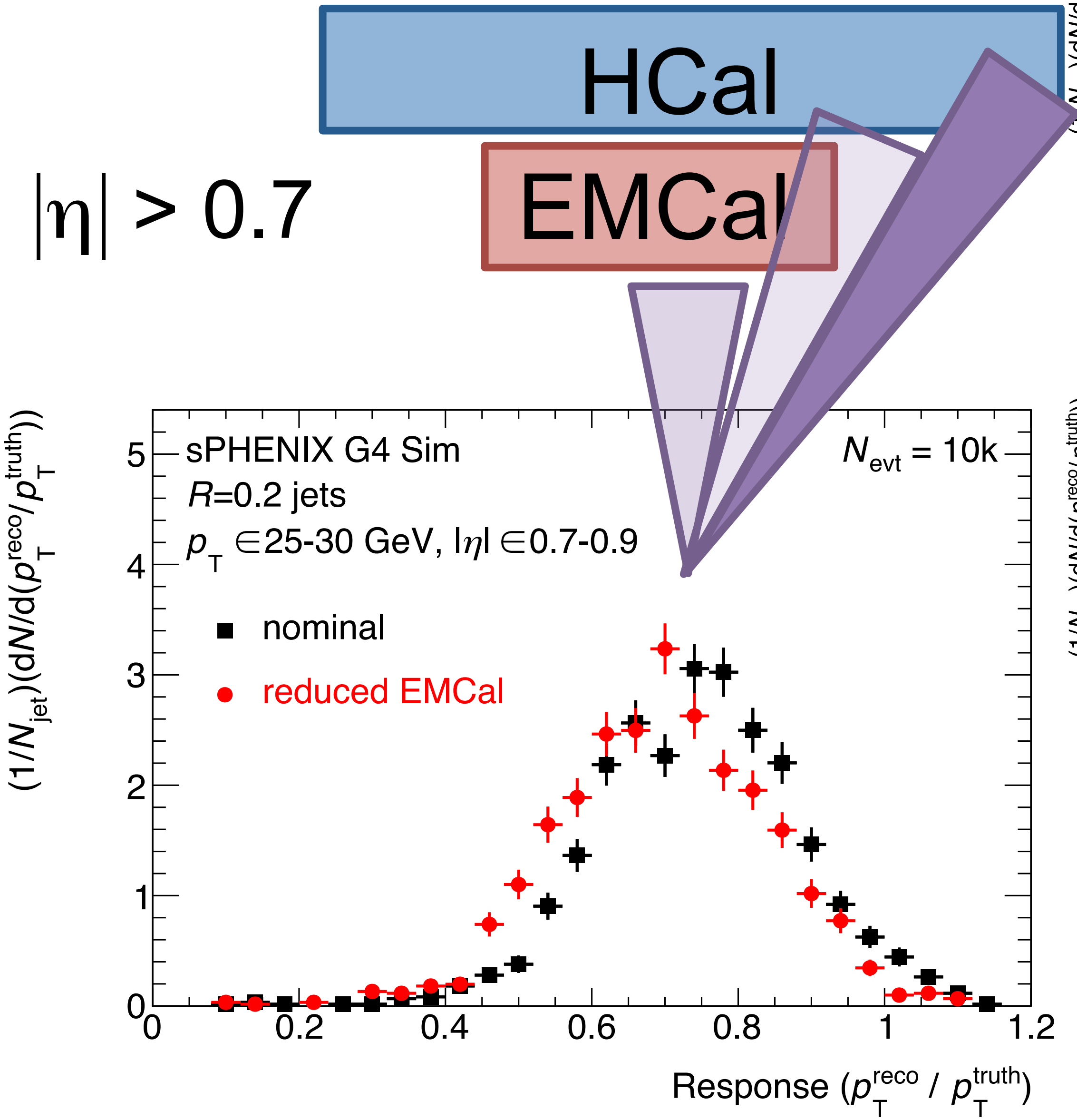


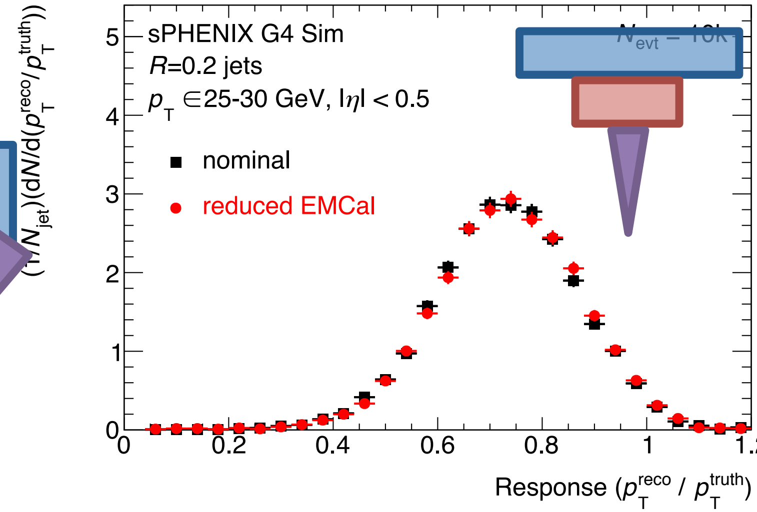


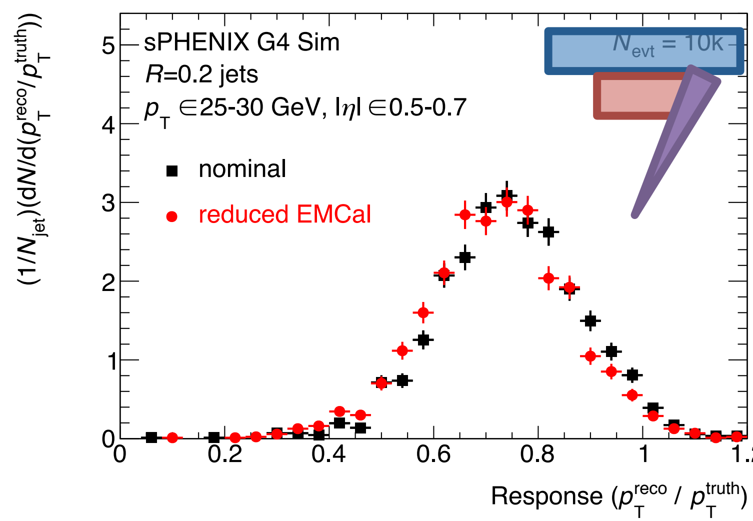
-2.5% shift to the JES

1/2 EMCal

$|\eta| > 0.7$



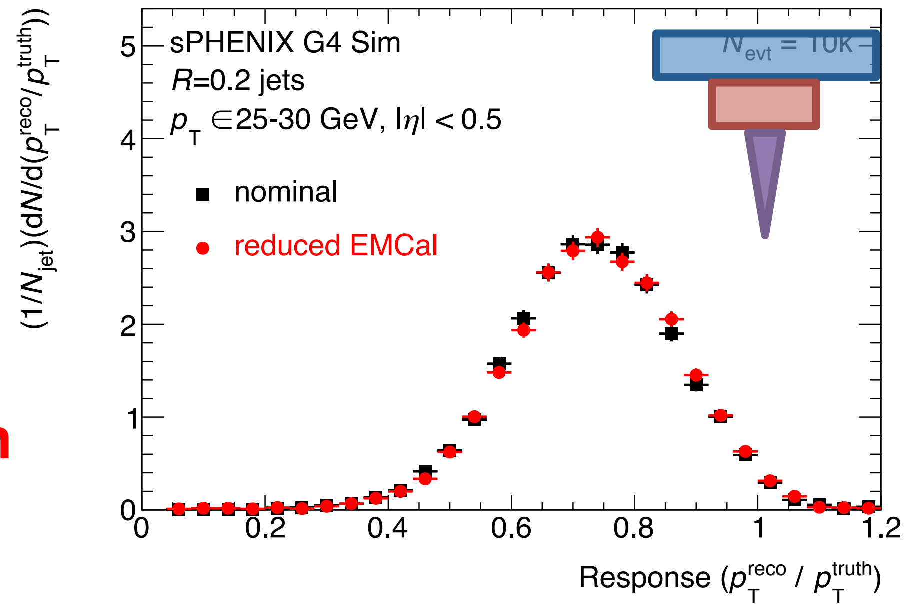


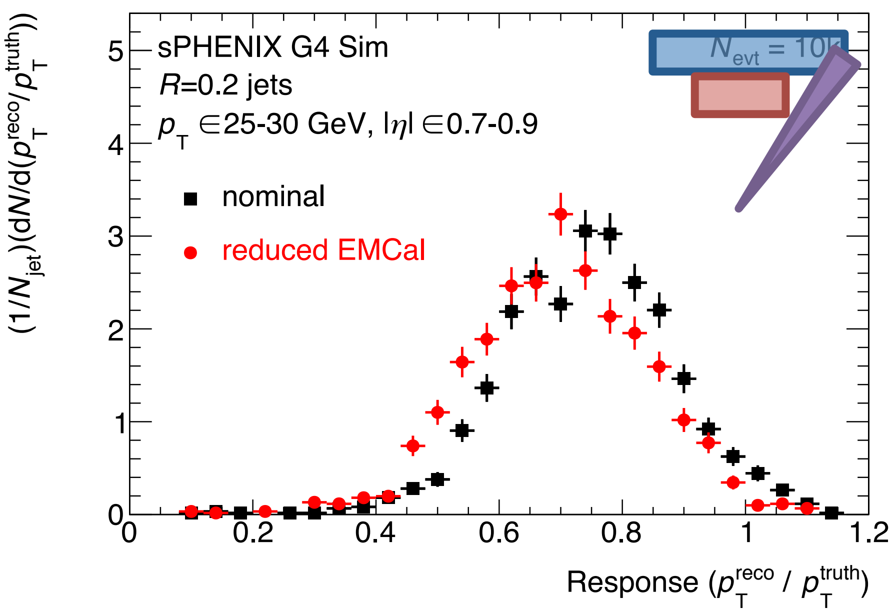


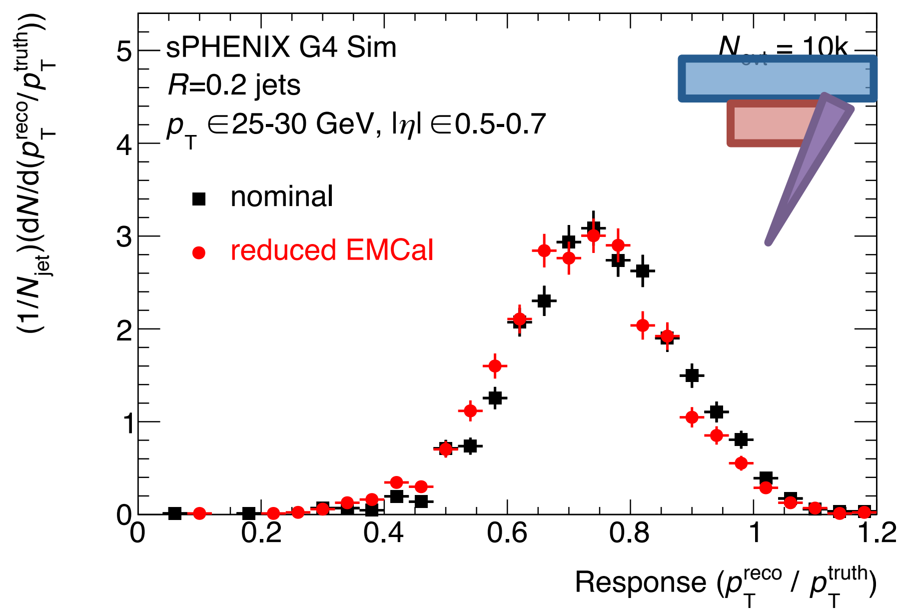
-5% shift to the JES

1/2 EMCal

- HCal can measure the jet energy EM component
- Does not study how detector-level UE fluctuations would be affected
- **Does not quantify sys unc due to η-dependent jet energy correction**
  - Flavor-dependence?
  - Fragmentation?



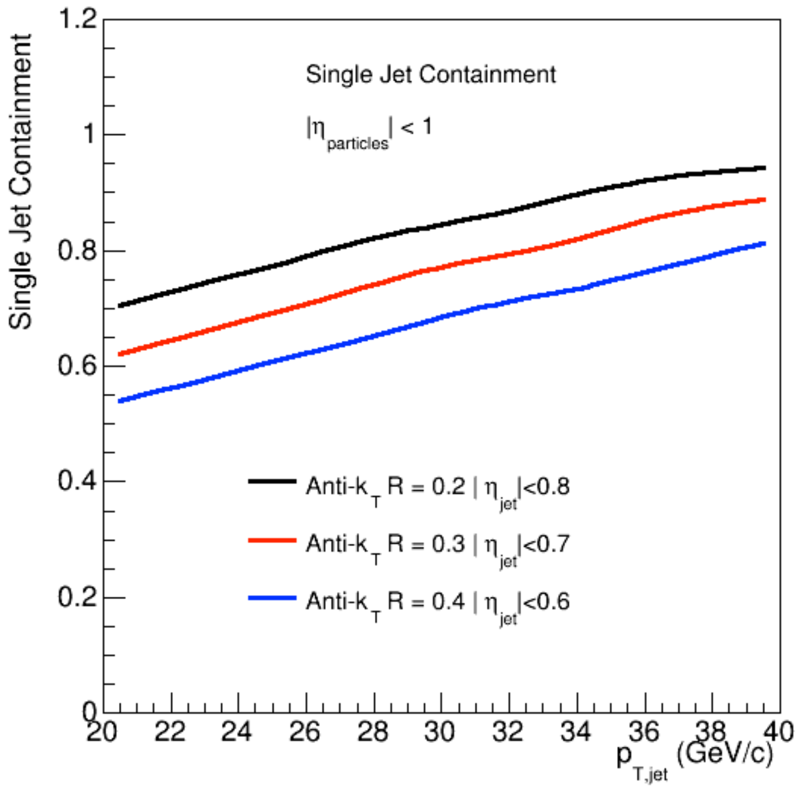


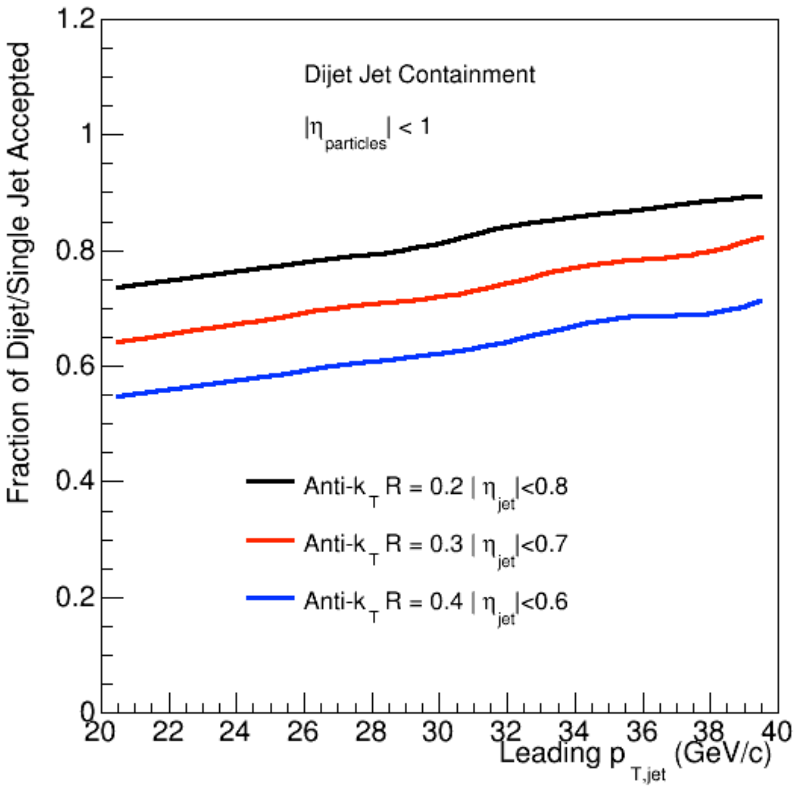


Jet Containment vs R – MIE

For fully contained jets, acceptance is reduced with increased R

- For R = 0.4 jets at 20 GeV, acceptance reduces the total reconstructed dijet cross-section ~30%
- Conditional cross-section is ~70% for R = 0.2 jets

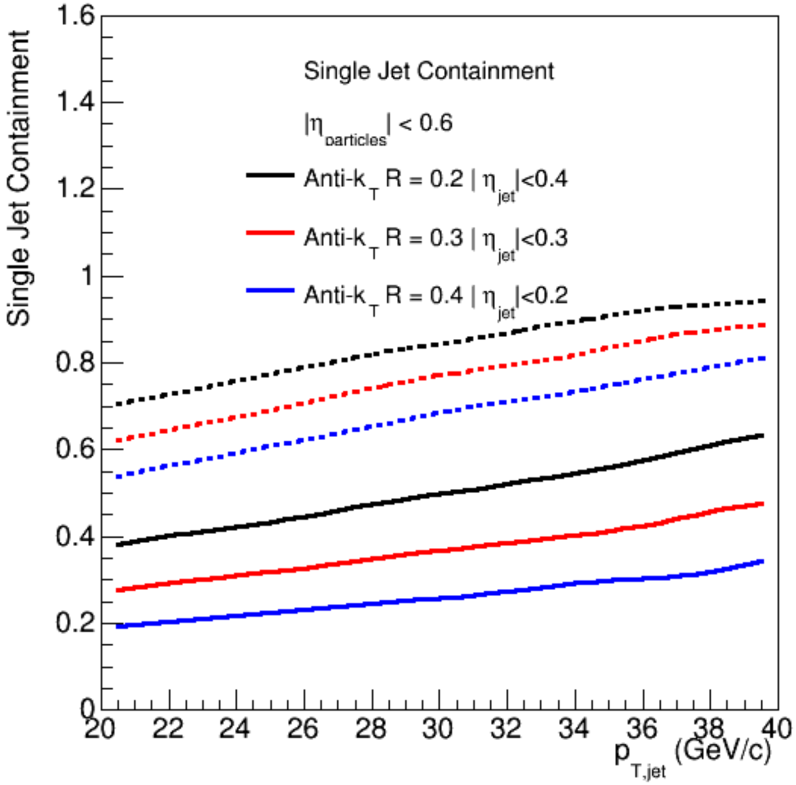


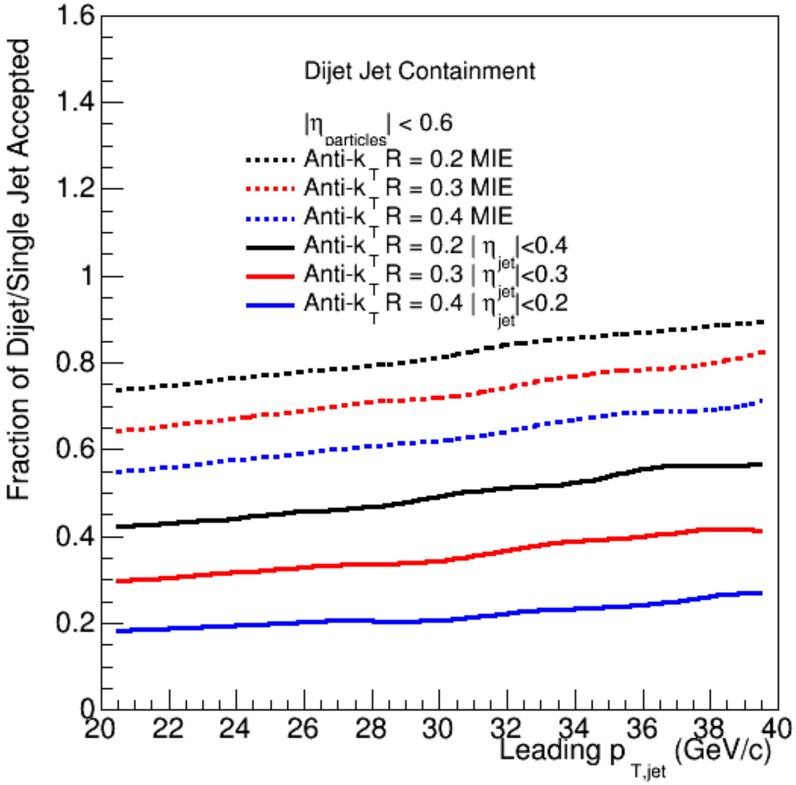


Jet Containment vs R – Reduced EMCAL

For R = 0.4 jets at 20 GeV, acceptance reduces the total reconstructed dijet cross-section to ~4% from 30% from the MIE

- An order of magnitude different





Next Steps – Calorimeter Response

- The simulations shown thus far have tested the response of the calorimeter to inclusive jets
  - The details of the fragmentation pattern are also important!
- Test the effect of the thin HCal versus fragmentation
  - High p_T hard fragmenting jet may punch through the calorimeter
  - Simulate single high p_T hadrons or
  - Directly look at the fragmentation of the existing high p_T jet simulation data set
    - Statistics? Effect increases with z

Tracking Simulation Tasks

Take same set of N_{evt} = 10k, p_T = 50-55 GeV dijet events

- Do tracking-only sim for multiple tracking options
- Repeat for PYTHIA only *and* for HIJING-embedded

For 3 (e.g.) tracking configurations, this is 10k events x 3 configurations x 2 embeddings = 60k w/ tracking-only sim

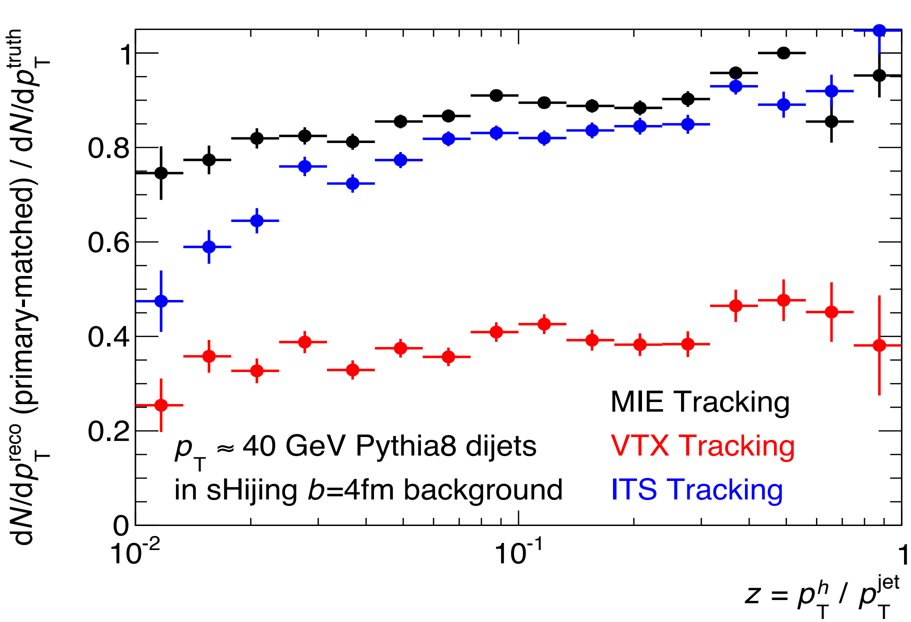
- **Key observable: efficiency, fake rate, resolution vs. z**
- **Requires TPC simulation → A few days**

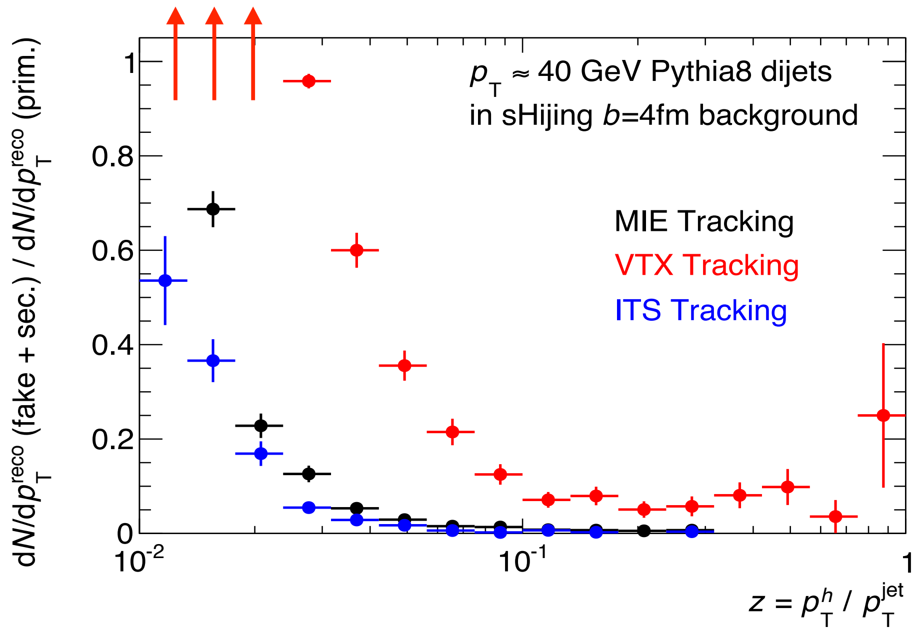
Previous Tracking Evaluation Work

G4 tracking studies have been underway in Simulations meeting

- On next slide, study of charged particle performance for 40 GeV dijets, with some current (at the time) tracking options
- Note: “VTX” on next slide is 2 layers with existing dead areas, not one reconfigured layer...

- Comparing tracking configurations: **MIE** ideal 7-layer silicon, reused **VTX** pixels + ganged strips, 7 layer ALICE **ITS**
- G4 tracking simulated, embedded in b=4fm Hijing background
- Fragmentation functions for p_T ~40 GeV dijets





Truth-matched $\dfrac{dN/dp_T^{reco}}{dN/dp_T^{truth}}$

Fake+secondary truth-matched $\dfrac{dN/dp_T^{reco}}{dN/dp_T^{reco}}$

How big are corrections for efficiency and p_T resolution together?

What is the relative fake rate inside jet cone?

Potential Additional Simulation Tasks

If resources and time are available could extend to:

- Explore multiple p_T bins
- Explore quark/gluon response differences at low p_T
- Explore effects of UE

If resources and time are available could extend to:

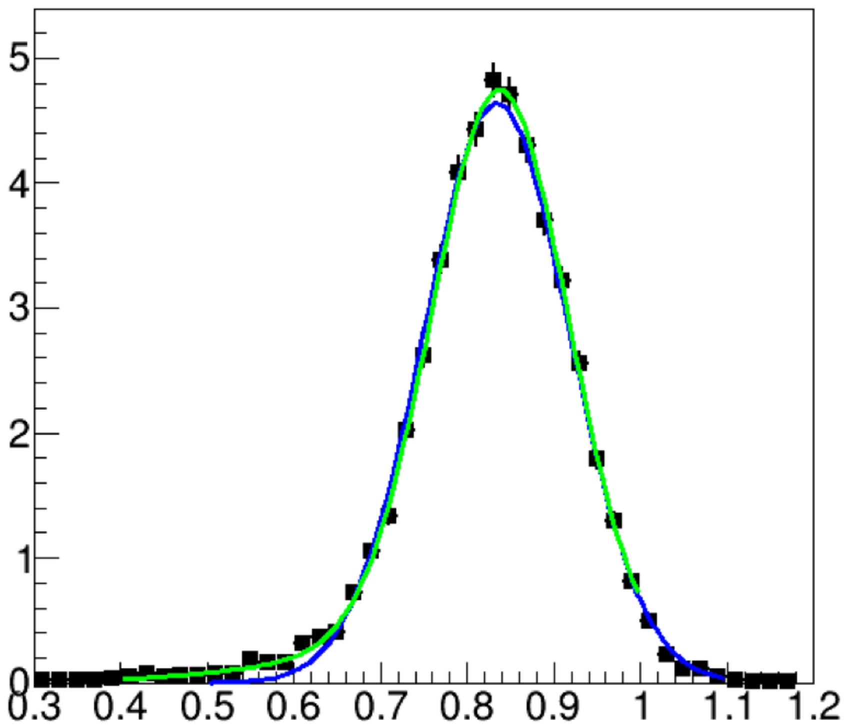
- Run 10k+ pure-HIJING events, w/ fast-sim calo matching?
- Estimate statistical uncertainties vs. z for the FF of p_T = 40, 50, 60 GeV jets?
- Toy unfolding to translate performance into FF systematics?

Conclusions

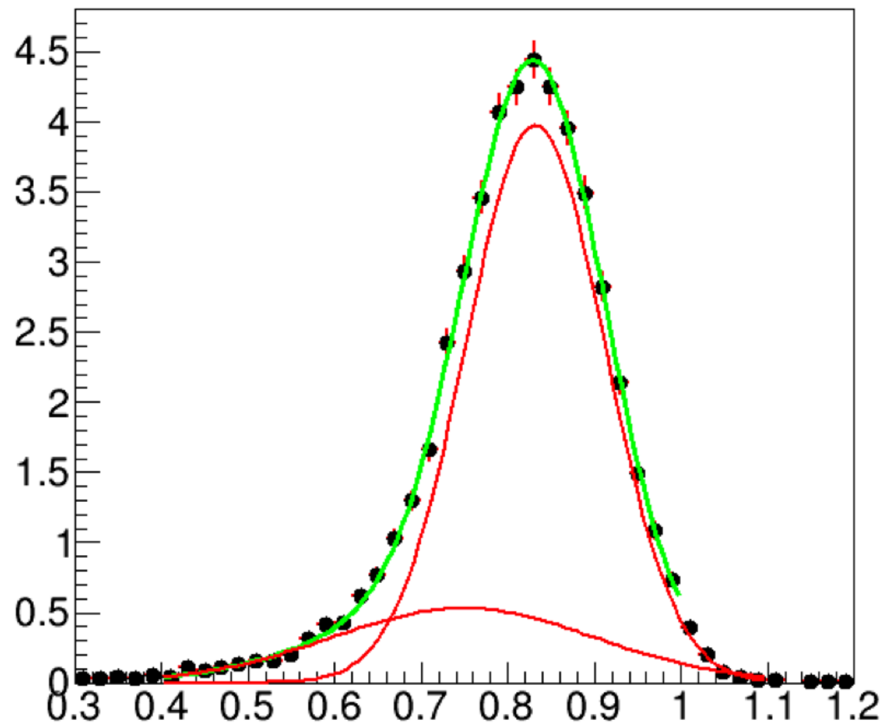
- Ganged EMCal – No effect on Jet Response
- Thinned outer HCal – Small shift in JES for inclusive jets
  - Requires more investigation → fragmentation effects
- ½ EMCal
  - JES has a -5% shift for $|\eta| > 0.7$ due to HCal only
  - Unfolding may be complicated in overlap region
  - Dijet cross-section for R = 0.4 jets reduced ~ order of magnitude if fully contained
- We are prepared to run tracking studies when available
- Triggering descoping options will not have a large effect
- Depending on resources, additional studies with HIJING+ embedding/ other kinematic selections may be performed

Back-Up

Jet unfolding and non-Gaussian response

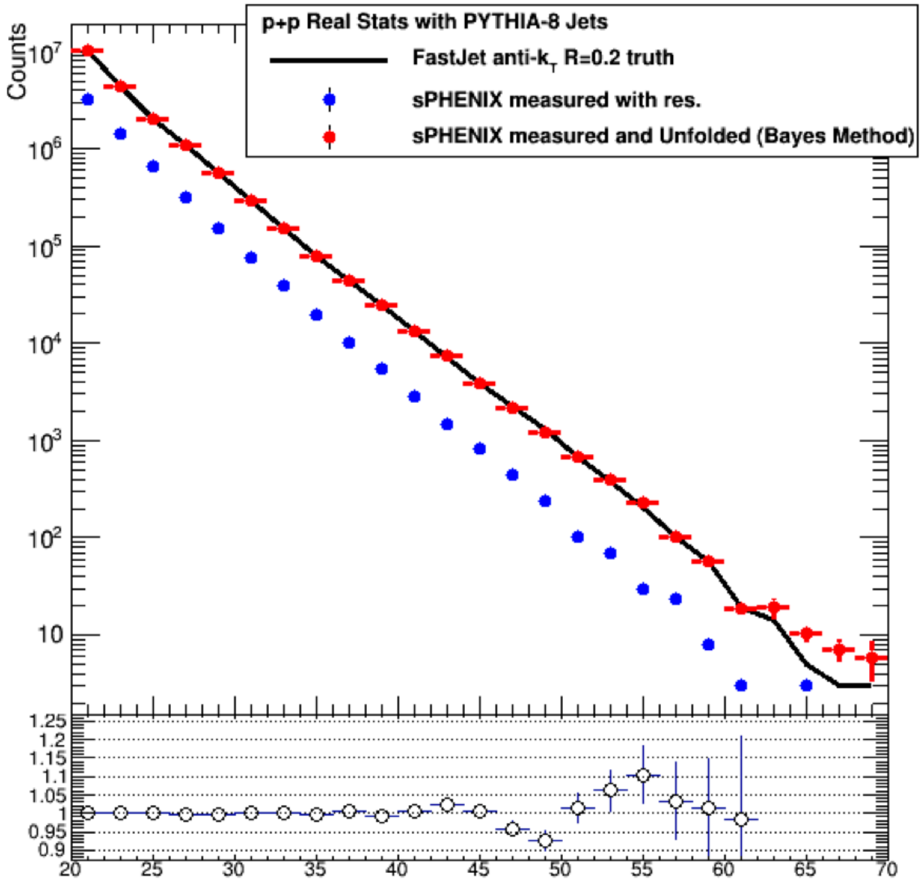


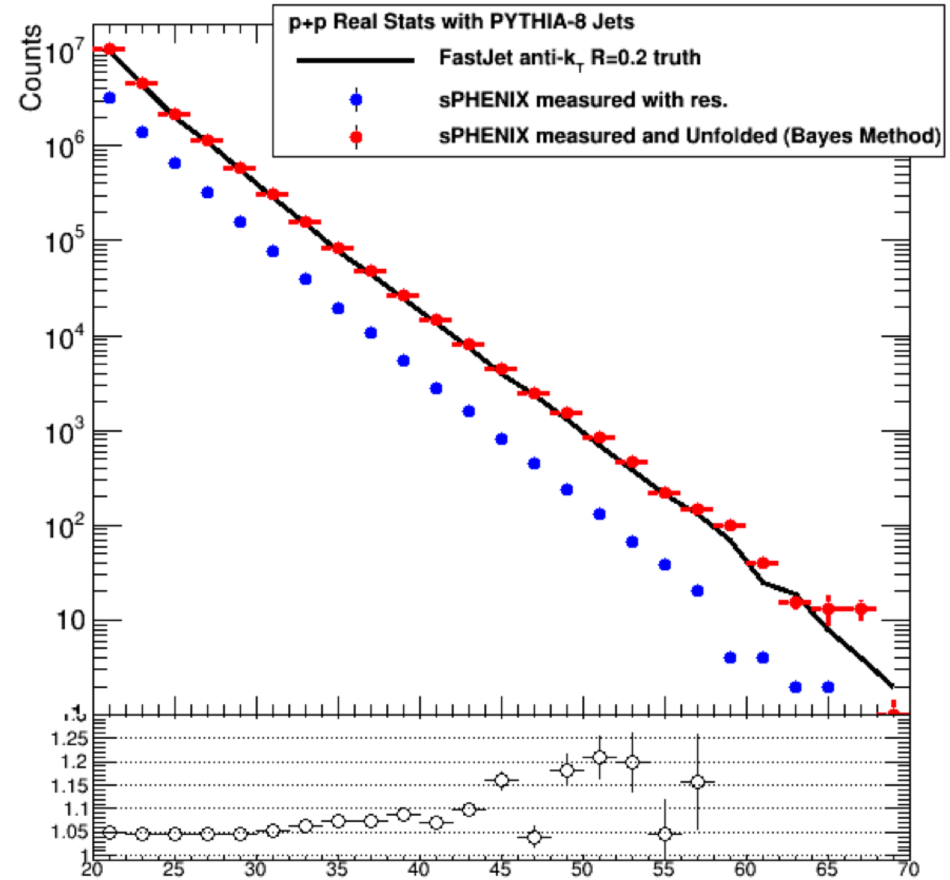
Dennis’ GEANT Calorimeter energy response to 50-55 GeV jets.



Dennis’ GEANT Calorimeter energy response to 50-55 GeV jets.

Now with thinner outer HCal. Results in second component Gaussian (low-side tail contribution).





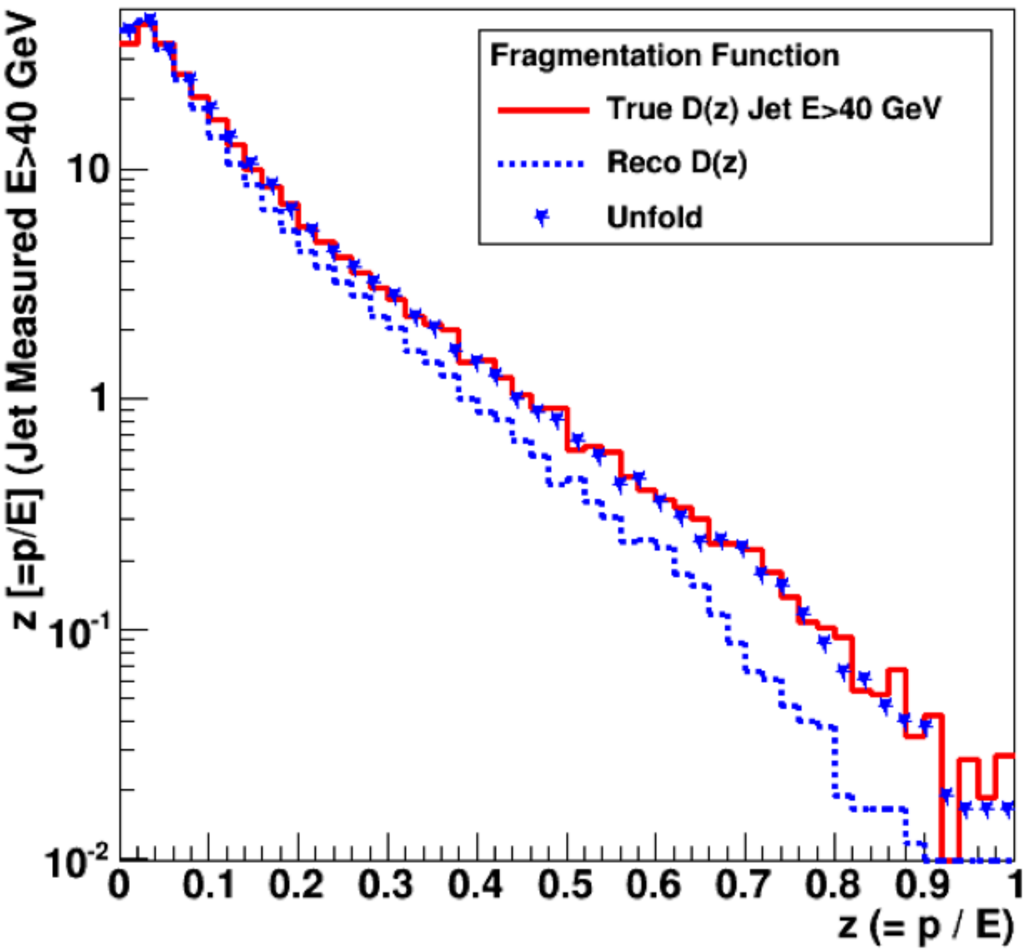
Use identical energy resolution function – including low-side tail with thinner HCal – for “fake data” and “response matrix”.

Bayes unfold works well – resulting unfold/truth ratio around one.

Use energy resolution function with low-side tail for “fake data”, but then generate response matrix completely ignoring the low-side tail (just the peak Gaussian).

Systematic offset of ~ 5% and then larger at the highest pT ~ 15-20%. This is an extreme case (just an initial test).

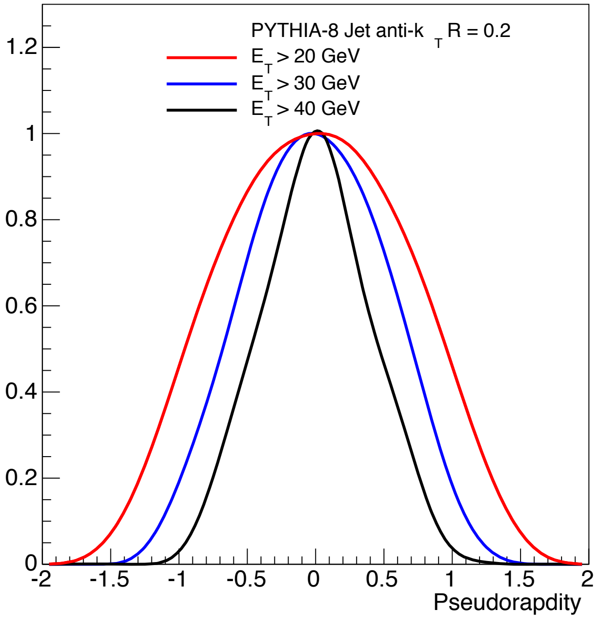
Fragmentation Function MIE



pCDR Statements

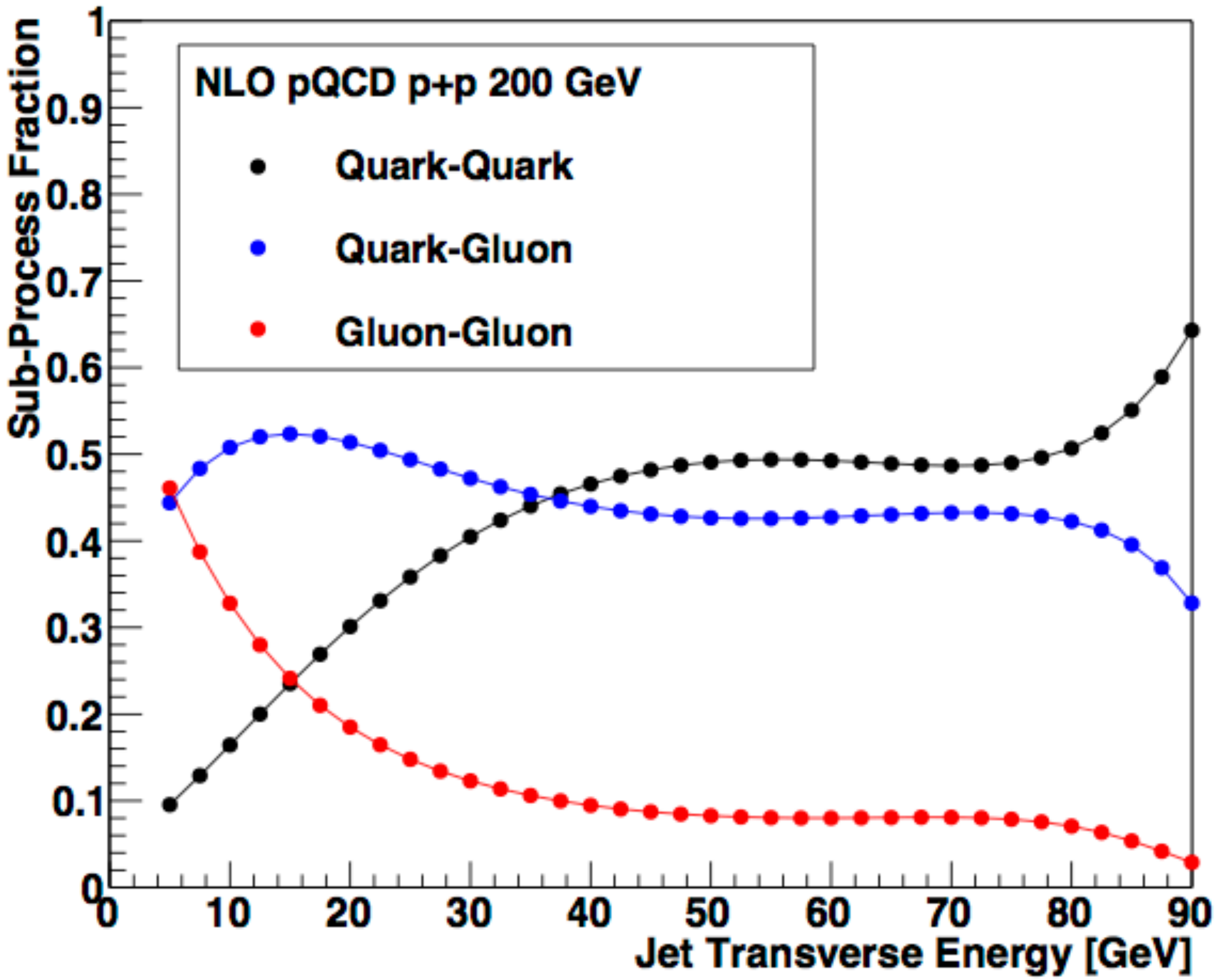
- **Jets** The key to the physics is to cover jet energies of 20–70 GeV, for all centralities, for a range of jet sizes, with high statistics and performance insensitive to the details of jet fragmentation.
  - energy resolution < $120\%/\sqrt{E_{\mathrm{jet}}}$ in p+p for R = 0.2–0.4 jets
  - energy resolution < $150\%/\sqrt{E_{\mathrm{jet}}}$ in central Au+Au for R = 0.2 jets
  - energy scale uncertainty < 3% for inclusive jets
  - energy resolution, including effect of underlying event, such that scale of unfolding on raw yields is less than a factor of three
  - jets down to R = 0.2 (segmentation no coarser than $\Delta\eta \times \Delta\varphi$ ~ 0.1 × 0.1)
  - underlying event influence event-by-event (large coverage HCal/EMCal)
  - Energy measurement insensitive to softness of fragmentation (quarks or gluons) — HCal + EMCal
  - jet trigger capability in p+p and p+A without jet bias (HCal and EMCal) • rejection (> 95%) of high p_T charged track backgrounds (HCal)

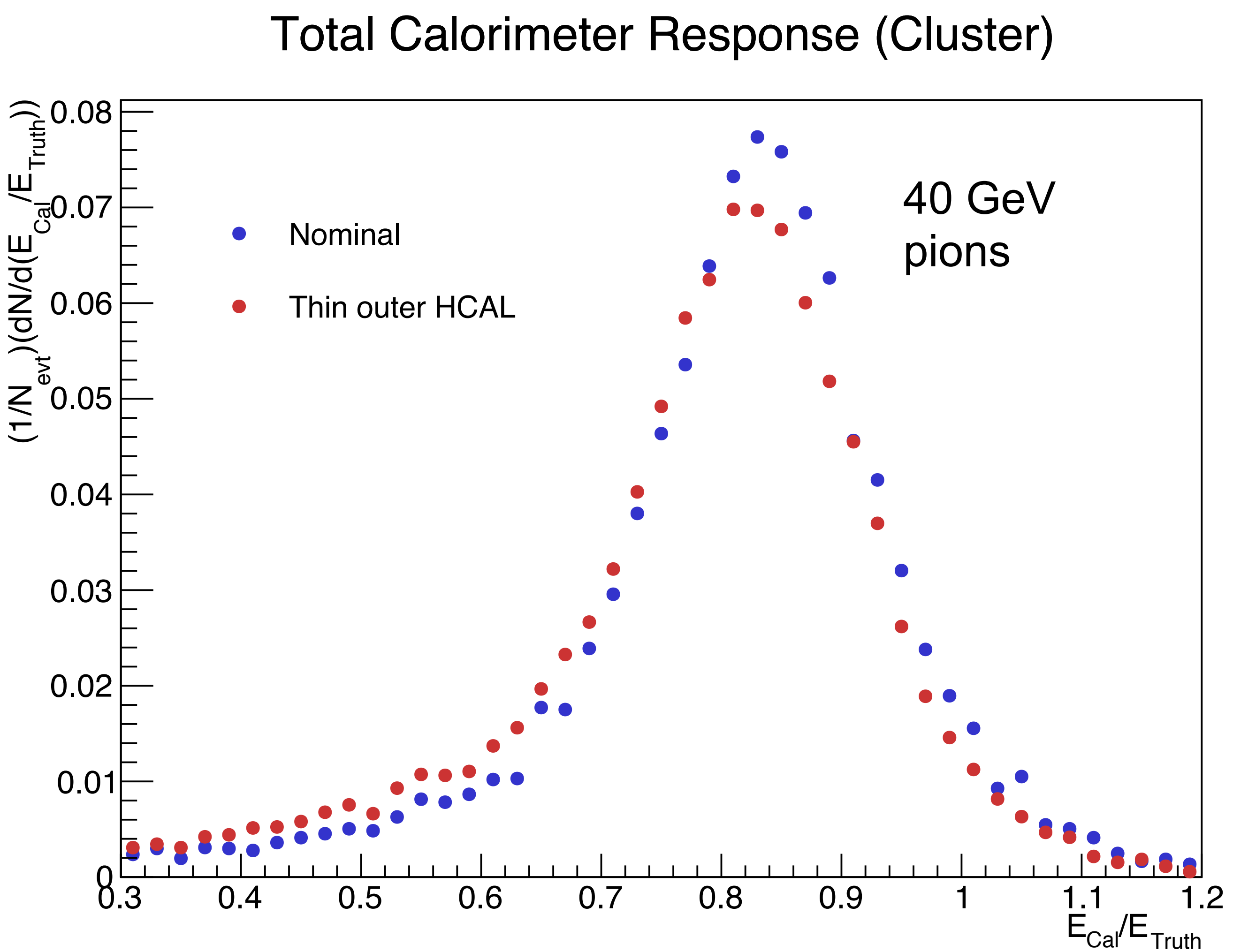
EMCal Acceptance – DiJet containment



- Reduced acceptance → Reduced DiJet statistics
  - Generator only analysis
  - Especially key for R > 0.2 and/or low p_T jets
  - Note: Pythia 8 tune not identical to the MIE, slightly better performance

Flavor Content





Total Calorimeter Response (Cluster)
(1/N_evt)(dN/d(E_Cal/E_Truth))
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
E_Cal/E_Truth
Nominal
Thin outer HCAL
40 GeV pions